

NASA Contract Report 181777

High Temperature Be Panel Development

R. Hardesty, M. Jensen, and L. Grant

Electrofusion Corporation
Fremont, CA 94555

Contract NAS 1-18613
May 1989



National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665-5225

HIGH TEMPERATURE BE PANEL DEVELOPMENT
for NASA/LANGLEY RESEARCH CENTER
NASA Contract #NAS-1-18613

I. INTRODUCTION

Beryllium metal is used on many satellites in a variety of applications, including central cylinders, solar array and antenna booms, struts, radiators, and various other support structures (Reference 1). Beryllium has also been used in aircraft applications, missiles, guidance components, and scan mirrors, and it is used on the Space Shuttle (Reference 2). These technologies to produce beryllium, as well as to machine and join it to form final assemblies is currently available to major aerospace companies. However, current applications generally utilize beryllium in relatively benign environments where long-term service at high temperatures is not required.

In fabricating beryllium structural panels for high temperature applications, two main factors to be considered are the understanding of the fundamental behavior of the materials to fabricate the panel, and the selection and application of appropriate joining techniques. Currently potential techniques for joining beryllium including brazing, diffusion bonding, welding, and epoxy bonding, with brazing generally being the method of choice for most elevated temperature applications. However, existing test information of brazed beryllium joints is limited to temperatures below about 600°F. Because proposed hypersonic vehicles will require very lightweight, built up structures with capabilities well above this temperature, the present initial program was undertaken to review, select, and evaluate braze alloy systems with the potential for fabricating beryllium components with load carrying capabilities up to 1200°F.

II. TECHNICAL APPROACH

A literature survey was performed and background records were reviewed to guide selection of candidate braze alloys with potential load carrying capability in beryllium structures up to 1200°F. The general approach of the test

program was to use brazed lap shear specimens to screen the braze alloys, select two of the most promising alloys, and use them to fabricate 4" square edgewise compression panels for evaluation. Lap shear specimens and compression panels were tested at room temperature, 300°F, 600°F, 900°F, and 1200°F.

III. BRAZE ALLOY SELECTION

In utilizing information gained from our literature survey and EFC's overall capabilities in beryllium joining, we selected BAg-18, BAg-19, Palcusil 15, and Cusil ABA. The reasons for these choices are as follows:

BAg-18: BAg-18 has been used extensively in beryllium fabrication. This alloy has successfully been used in elevated temperatures up to 600°F. However, no existing data is available for temperatures up to 1200°F. Where there are indications that at elevated temperatures BAg-18's strength will drop off, there is no existing data that will correlate this, and therefore, BAg-18 was one of our selections in order to obtain this data.

BAg-19: BAg-19 has previously demonstrated or indicated that higher temperatures should not affect BAg-19 as much as BAg-18. BAg-19's chemistry is comprised of 92% silver, 7.8% copper, and .2% lithium. The higher silver content of BAg-19 in comparison to BAg-18 (60% silver, 30% copper, and 10% tin) should generate higher strengths at elevated temperatures.

Palcusil 15: Palcusil 15 was chosen for a number of different reasons. First, the chemistry of Palcusil 15 is 65% silver, 20% copper, and 15% palladium. In our literature search we reviewed applications where the addition of palladium to some braze alloys would increase the strength of the braze alloy, and allow the alloy to fill large gaps and span large braze surfaces. For large structures, this would be an advantage.

Cusil ABA: The chemistry of Cusil ABA is 63% silver, 1.5% titanium, and the remainder copper. The advantage that Cusil would have is the ability to use titanium as a gettering agent to remove any residual oxide from the braze faying surfaces, and provide high strength braze joints.

Please see Table I comparing the chemistries of each of the alloys.

IV. LAP SHEAR SPECIMENS

Specimen Design:

EFC chose a lap shear specimen design as shown in Figure 1 manufactured from cross-rolled beryllium sheet material. This specimen design was selected because it was both economically easy to produce and test. Where it may not be consistent with most applications, it has provided very consistent results during screen tests like these. Consistency was the key in our selection of an elevated temperature test scenario. We wanted to guarantee that simplicity and repeatability was observed. The shear test specimens were placed within the fixtures shown in Figure 2 for testing. This test setup was placed inside a box furnace around an Instron machine. Therefore, our goals of simplicity and repeatability were due to having limited access during the testing process.

Brazing Procedures:

Prior to brazing, each of the specimens were prepared by placing them into a solution of HF-HNO₃ acid and then rinsing them with DI water and drying them with dry nitrogen. All braze alloys were acetone wiped, along with the detail coupon prior to layup for joining. The time between cleaning and brazing was kept to a minimum, typically within one hour. No specific wetting, stop-off or fluxes were used for joining. During the brazed layup, the coupons were brought together with a .001 mil thick braze alloy foil in between. After brazing in a partial vacuum, the coupons were machined undercutting the faying surface by .007" as shown in Figure 1. This was done to make sure that only shear surfaces would be tested during elevated temperature testing. One braze run per alloy was utilized for these trial purposes. Prior to that specific braze run we had a trial run to verify braze parameters. All alloys showed good wetability during these runs except for the Cusil ABA. After several attempts, this specific alloy continued to show poor bonding strengths. Under final machining operations, the Cusil ABA coupons separated. Where all coupons were reviewed for metallurgical joining visually, no specific NDT test was used except for verification during machining that the coupons did not separate.

Screening Tests:

An Instron machine was setup utilizing a box furnace and the test fixture shown in Figure 2. The furnace around the test fixture is a box type furnace modified for this specific application. Prior to the testing of each individual lap shear coupon, the fixture was adjusted to a slide fit on the specimen to be tested, and the bolts were secured by finger tightening. By finger tightening, it should prevent binding of the fixture during testing from the lateral forces generated by eccentric loading. After snugging the coupon together by finger tightening only, the specimen was rechecked to assure a slide fit was still present.

The results of testing are shown in Table 2 attached.

V. COMPRESSION PANELS

Panel Design

Each of the compression panels were fabricated from beryllium SR-200E cross-rolled beryllium sheet. The face sheets were .060" thickness and the egg-crated core elements were .020" thick each. Along the edges where test loads were applied, 304 stainless steel mounting pads were attached metallurgically during the braze process. The geometry of the part can be seen in Figure 3.

Prior to brazing, all details were cleaned with an HF-HNO₃ solution, then rinsed with DI water and dried with dry nitrogen. This was done just prior to braze layup. Braze alloy was cleaned with acetone, and the overall assemblies were layed up and brazed. No wetting agents, fluxes or stop-offs were used. Braze alloy was used in the form of .001" thick foil. During the braze process, clamping forces were used from the top and bottom. A partial vacuum was used during brazing and liquidous temperatures were observed during the brazing process. All panels were brazed in one step, and one panel was brazed at a time. After brazing, the parts were dimensionally inspected to verify conformance to Figure 3, and a visual inspection was utilized to assure metallurgical joining.

Panel Testing:

Each of the panels were tested by placing them into the setup as shown in Figure 4. An Instron machine was utilized with a box furnace around the test zone where the individual panels would be placed. The panels were placed within the confines of the configuration shown, and then a load was brought to bear until the load fell off as indicated by the Instron machine. When testing at temperatures, individual panels were brought up to temperature and held at that temperature until stabilized prior to bringing the load to bear. Test results are shown in Table III.

VI. RESULTS & DISCUSSION

The results obtained from the screening and edgewise compression panel testing are shown in Graphs I and II attached. In reviewing the shear test data, our goal was to choose a quantity of two braze alloy systems to continue edgewise compression panel testing. Our selection of the two alloys was based on the following criteria:

1. The braze temperature and how it affects raw beryllium material properties.
2. The brazed joint strength at elevated temperature.

In order for us to evaluate the effects of the braze temperature on the raw material, tensile test coupons per ASTM E-8 were placed into the initial braze runs on the shear test coupons. Testing was then performed at room temperature and the results are as follows:

<u>ITEM</u>	<u>BRAZE ALLOY</u>	<u>% DEGRADATION</u>
1	BAG-18	Negligible
2	BAG-19	20%
3	Palcusil 15	37%
4	Cusil ABA	19%

In using this chart in Graph I, we wanted to choose a braze alloy with a braze temperature having the least effect on the raw material; this was BAG-18. We also wanted to choose

an alloy that provided the highest joint strength at 1200°F, and that was BAg-19. While Palcusil 15 may have applications for the purposes of this study, edgewise compression testing was not performed.

Edgewise compressive specimens were created and tested, and the results are shown in Graph II attached. A set of 15 edgewise compressive test panels were created for both BAg-18 and BAg-19. Edgewise compression testing was performed per the test setup shown in Figure 4 at the appropriate temperatures. Graph II illustrates the load carrying capabilities of each of these alloy systems at room temperature to 1200°F. The mode of failure on these panels go from a catastrophic mode (see Figure 5) to a buckling mode at elevated temperature (see Figure 6). Both alloy systems, BAg-18 and BAg-19, exhibited the ability to carry loads up to 1200°F.

Since no previous information was available for elevated strengths of these braze alloy systems at the temperatures tested, a comparison cannot be made. However, our goal of a high strength braze alloy at elevated temperature was not fully realized in this program. While the graphs and information above do show that some strength does exist at 1200°F, it's not as substantial as we would have liked.

VII. SUMMARY

Joint strength for high temperature beryllium panel applications was defined using the alloy systems tested in this program. Of the alloys reviewed for the edgewise compression testing, three exhibited load carrying strength capabilities up to 1200°F. The results are published in this paper. The designer using values and creating brazed panels must allow for sufficient braze faying surfaces to carry the loads of his maximum operating temperatures.

REFERENCES

1. L. A. Grant, "Successful Applications of Beryllium Sheet Materials to Satellite Structures"
2. L. B. Norwood, "Application of Beryllium on The Space Shuttle Orbiter" from SAMPI Journal, May/June 1984, Vol. 20-3
3. Chapter 13 Reprint, "Joining II: Brazing and Soldering", from "Beryllium Science and Technology, Volume 2"
4. G. D. Cremer, J. R. Woodward and L. A. Grant, "Beryllium Brazing Technology", SAE Paper 670805, Solar Division of International Harvester Company
5. L. A. Grant, "Development of Beryllium Honey-combed Sandwich Composite for Structural and Other Related Applications", Prepared for NASA Under Contract #NAS8-21215.

LIST OF TABLES

Table I - Braze Alloy Compositions
Table II - Shear Specimen Screening Data
Table III - Test Report Form

LIST OF FIGURES

Figure 1 - Lap Shear Test Specimens
Figure 2 - Method of Shear Testing
Figure 3 - Edgewise Compression Panel Configuration
Figure 4 - Edgewise Compression Panel Test Setup
Figure 5 - Catastrophic Failure of Compression Panels
 at Low Temperature
Figure 6 - Buckling Failure of Compression Panels
 at High Temperature

LIST OF GRAPHS

Graph I - Ultimate Shear Stress vs. Test Temp
Graph II - Edgewise Compressive Specimen
Graph III - Concept Review & Design Schematic

TABLE I
BRAZE ALLOY COMPOSITIONS

AWS CLASSIFICATION	Ag	Cu	Sn	Li	P	Pd
B _{Ag} 18	59/61	Remainder	9.5/10.5	--	.025	--
B _{Ag} 19	92/93	Remainder	--	.15/.30	--	--
Palcusil 15	64/66	19/21	--	--	--	14.5/15.5
Cusil	63	Remainder with 1.5% of Titanium	--	--	--	--

TABLE II

SHEAR SPECIMEN SCREENING DATA

<u>ALLOY</u>	<u>R.T.</u> <u>psi</u>	<u>300°F</u> <u>psi</u>	<u>600°F</u> <u>psi</u>	<u>900°F</u> <u>psi</u>	<u>1200°F</u> <u>psi</u>
	24,385	23,044	18,841	4,973	988
BAG-18	20,431	--	20,058	13,541	1,832
	28,622	--	--	--	--
	27,656	26,318	29,314	9,727	969
	23,712	--	--	5,439	--
	21,164	--	--	--	--
	18,698	21,810	18,817	13,576	Be Failed Prior to Brazing Joint Shear
BAG-19	30,586	21,462	19,044	12,627	
	30,513	--	--	--	
	2,667	--	23,790	--	
	26,932	--	17,814	--	
	5,714	4,602	7,449	5,088	5,083
PAL-15	12,222	7,670	6,042	10,024	7,022
	13,932	--	--	--	--
	12,146	7,593	--	3,673	5,265
	63	--	--	--	--
CUSIL-ABA	210	--	--	--	--
	--	--	--	--	--

TABLE III

REV.

SK-11737-25

TABLE 111

TEST REPORT FORM

TABLE 111								ENGR"G	M. JENSEN	4/88
TEST REPORT FORM								MFG.		
								Q.C.		
PROCESS DESC: EDGEWISE HIGH TEMP. COMPRESSION TEST										
WRITTEN BY: M. Jensen										
ISSUE DATE: 4/88								PG. 1 OF 1		
S/N	BZ ALLOY	BZ LNG	BZ WIDTH	AREA	TEST TEMP.	YIELD (LBS)	COMMENTS			
001	Bag 18	2.730"	4.000"		300	31250	.006 Alloy	BZ #1		
002							Bad braze shifted.	BZ #2		
003	"	"	"		300	24500		BZ #2		
004	"	"	"		300	26000		BZ# 2		
005	"	"	"		R.T.	21000		BZ# 3		
006	"	"	"		R.T.	31250		BZ# 3		
007	"	"	"		R.T.	21750		BZ# 3		
008	"	"	"		600	23750				
009	"	"	"		600	20000				
010	"	"	"		600	14750				
011	"	"	"		900	17600				
012	"	"	"		900	7250	Folded over.			
013	"	"	"		900	No Test	End seperated from side.			
014	"	"	"		900	15700				
015	"	"	"		1200	2000	Broke at preload.			
016	"	"	"		1200	1000				
017										
018	Bag 19	"	"		R.T.	17750	Folded over.			
019	"	"	"		R.T.	16250	Folded over.			
020	"	"	"		R.T.	19750				
021	"	"	"		300	15500				
022	"	"	"		300	18000				
023	"	"	"		300	16700				
024	"	"	"		600	15250				
025	"						Lost			
026	"	"	"		600	13500				
027	"	"	"		600	10000	Folded over.			
028	"	"	"		900	11600				
029	"	"	"		900	6750	Folded over.			
030	"	"	"		900	8750				
031	"	"	"		1200	1100				
032	"	"	"		1200	1250				
033	"	"	"		1200	750				

FIGURE 1
Lap Shear Test Specimen

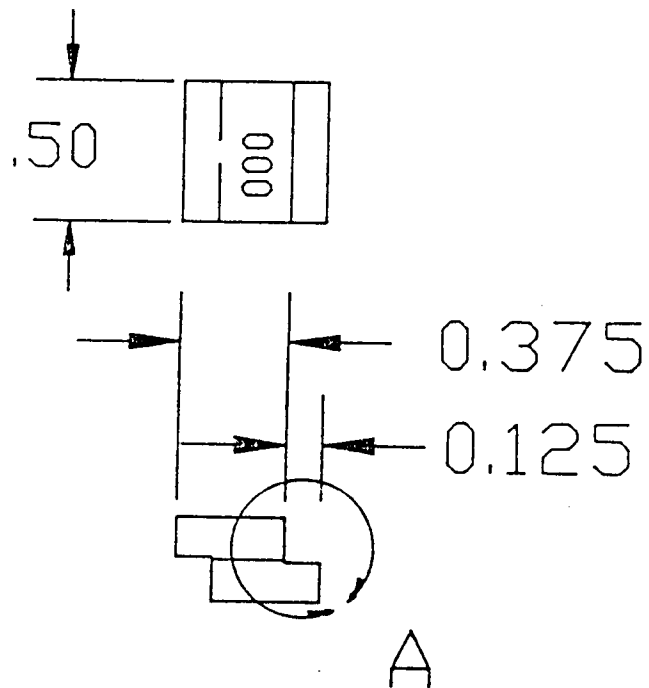
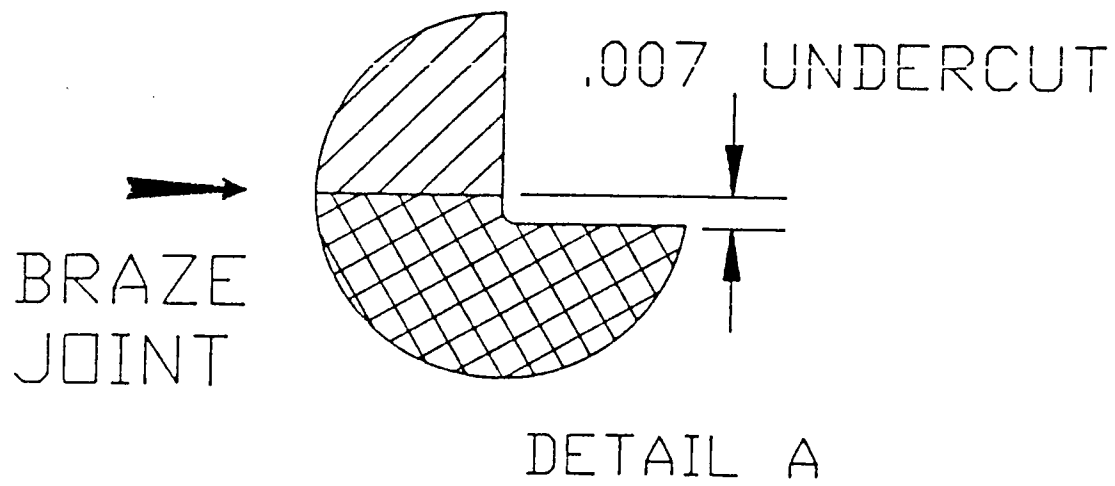


FIGURE 2
Method of Shear Testing

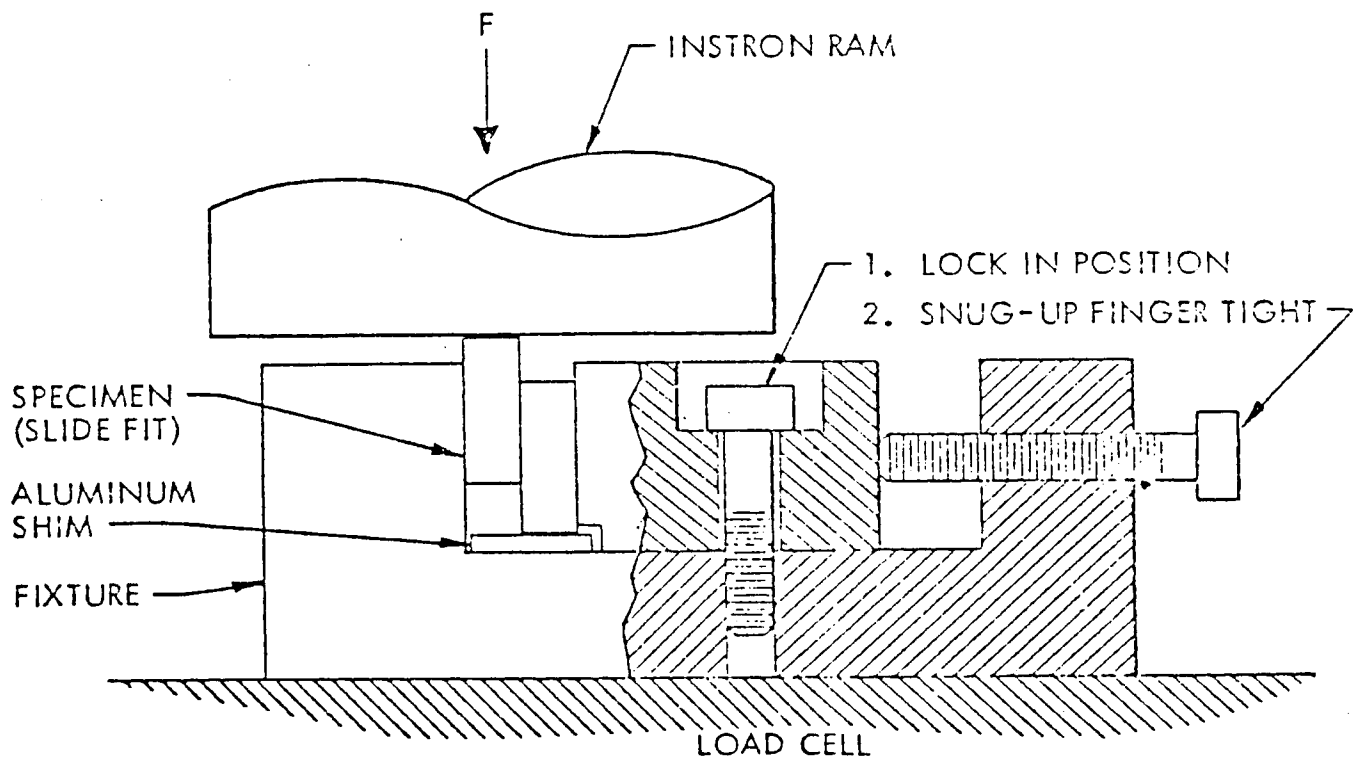


FIGURE 3
EDGEWISE COMPRESSION PANEL CONFIGURATION

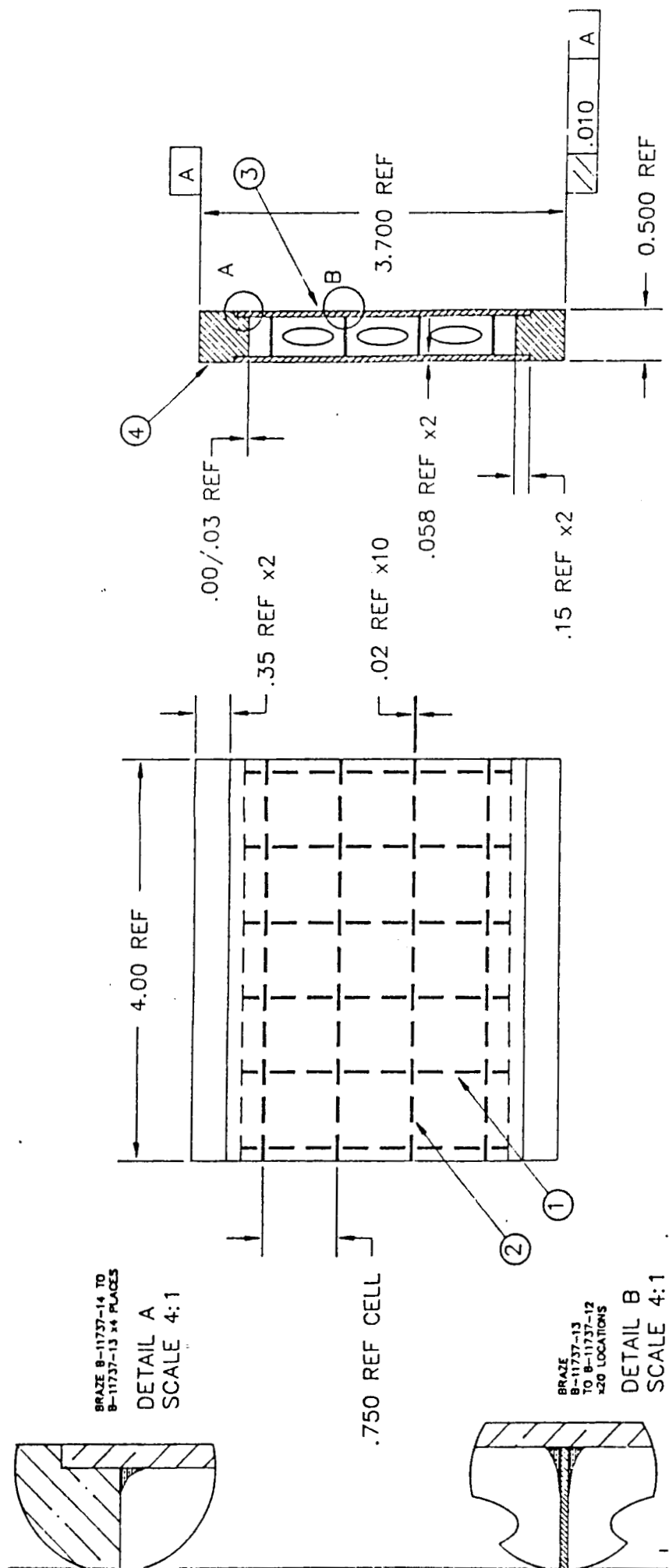
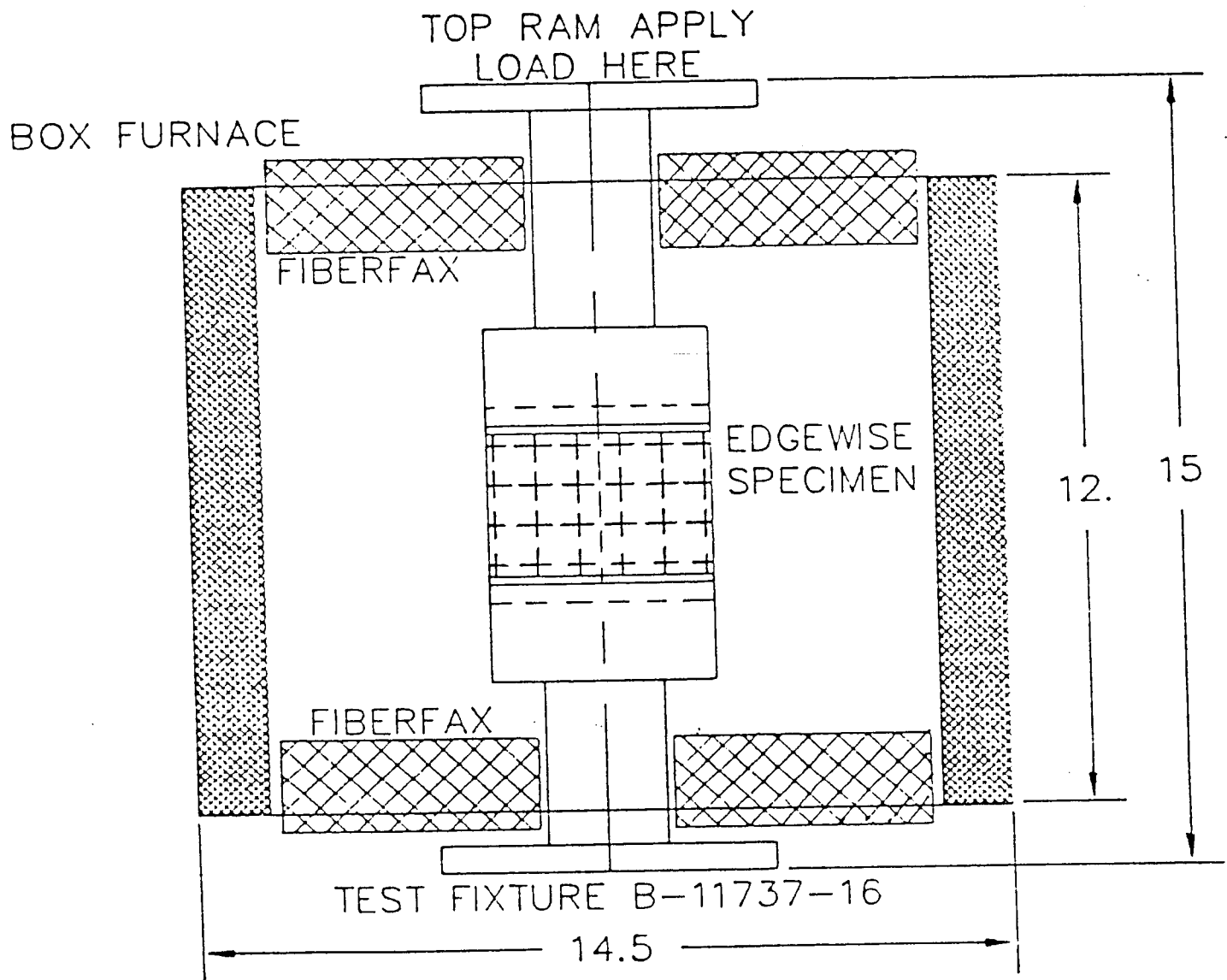


FIGURE 4
EDGEWISE COMPRESSION PANEL TEST SETUP



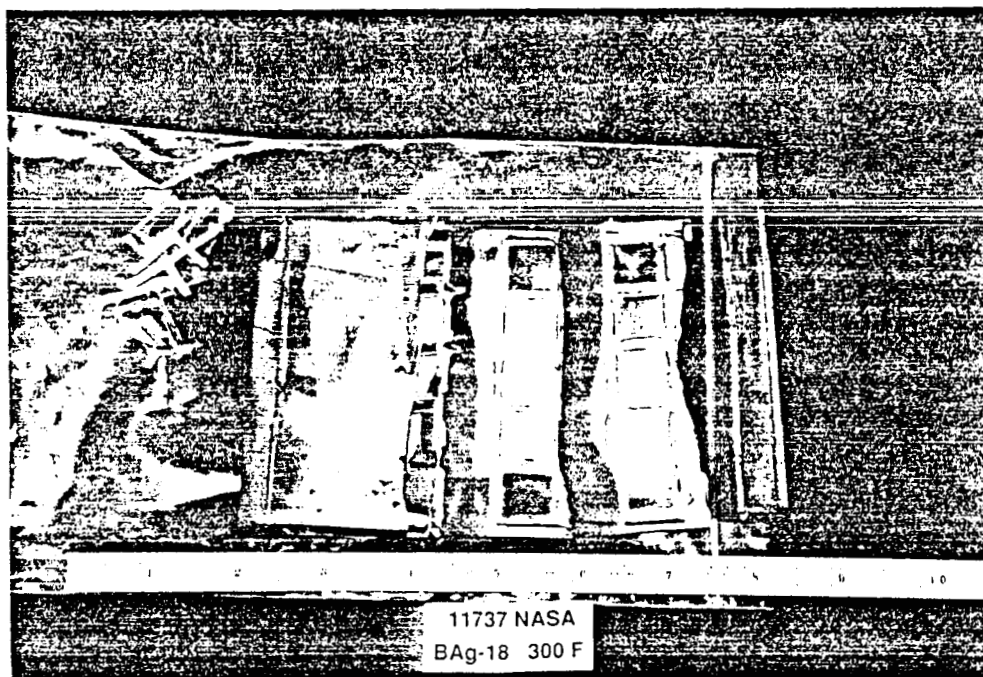


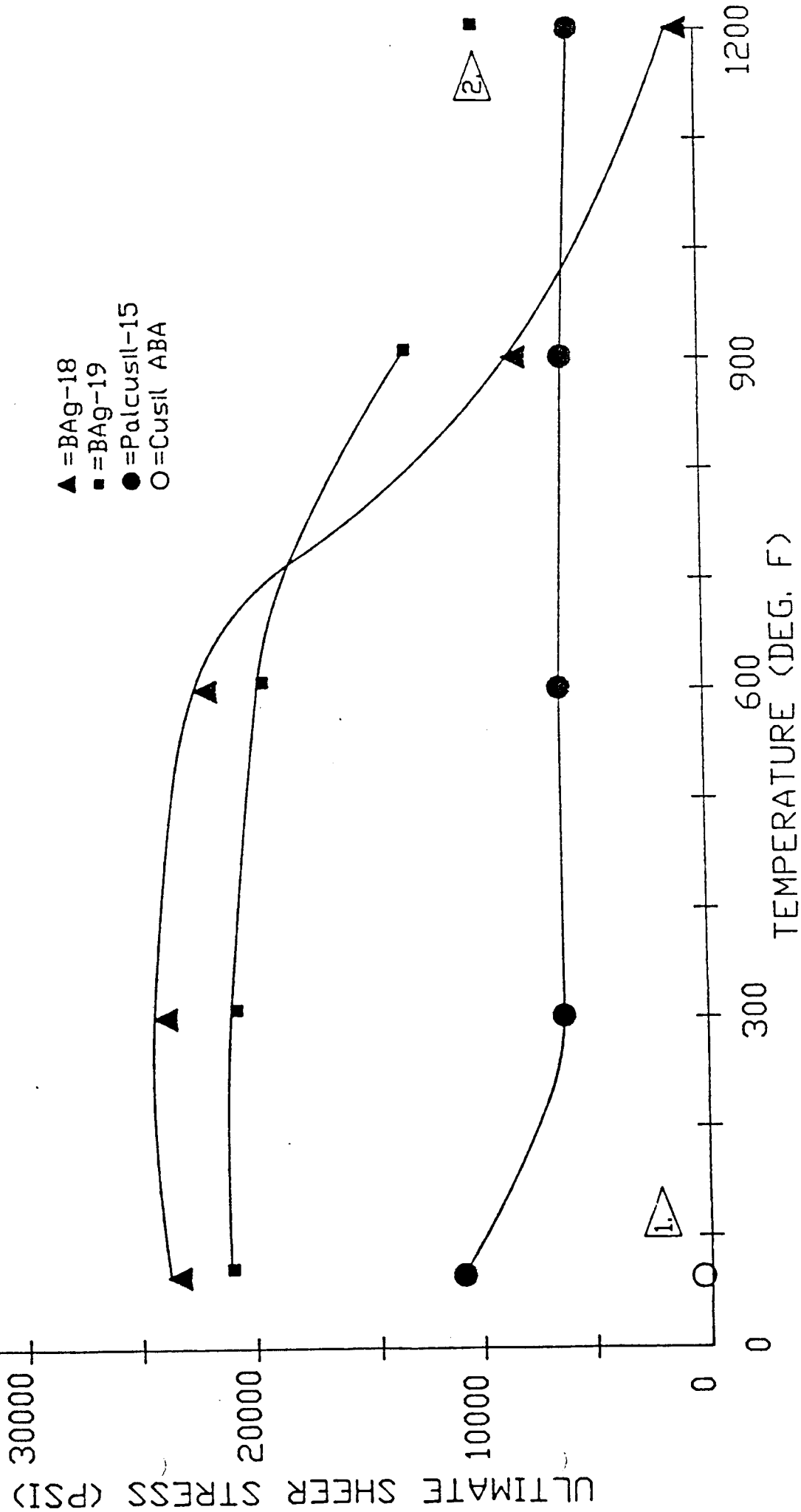
FIGURE 5: Catastrophic Failure of Compression Panels at Low Temperatures



FIGURE 6: Buckling Failure of Compression Panels at High Temperature

GRAPH I

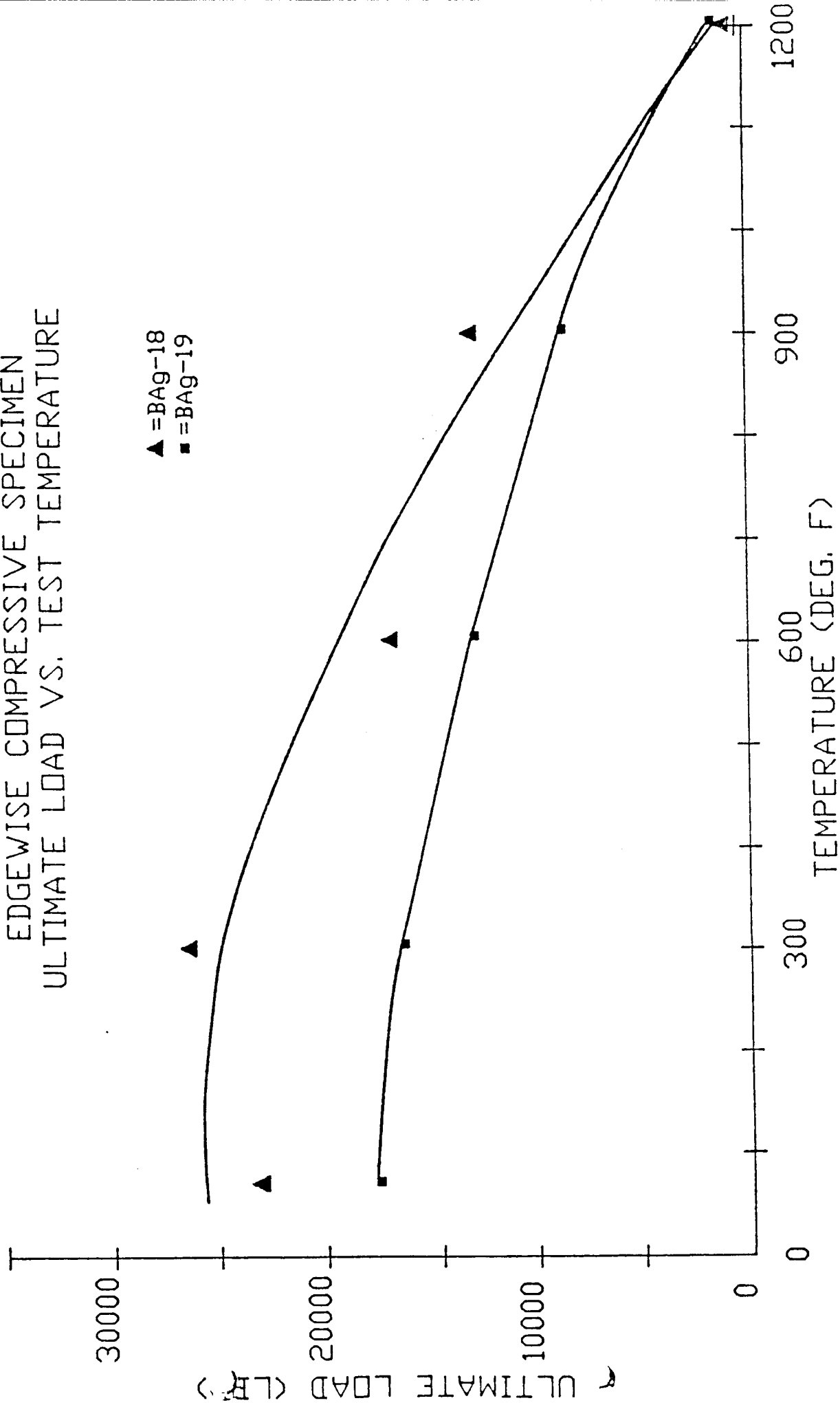
ULTIMATE SHEAR STRESS VS. TEST TEMP
Be BRAZED TO Be

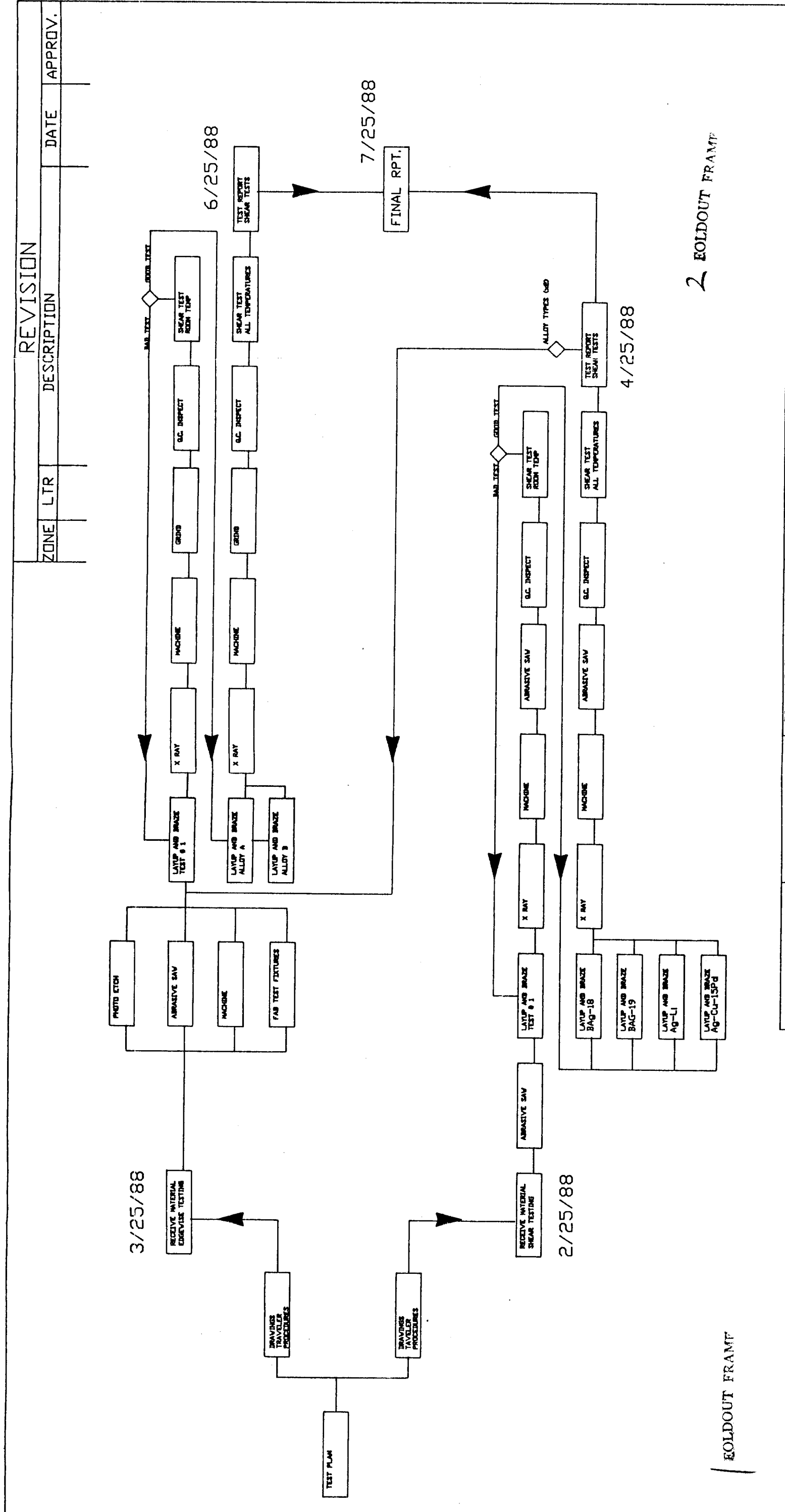


NOTES:

- 1. > ALL OTHER SAMPLES FAILED DURING MACHINING OR INSPECTION
- 2. > Be YIELDED BEFORE BRAZE JOINT FAILED Be YIELDED IN COMPRESSION AT 10000 PSI

EDGEWISE COMPRESSIVE SPECIMEN ULTIMATE LOAD VS. TEST TEMPERATURE





FOLDOUT FRAME

2 FOLDOUT FRAME

1. TEST TEMPS. ARE R.T., 300F, 600F, 900F, 1200F.

SECTION

	DIM ARE IN INCHES UNLESS OTHERWISE SPECIFIED TOLERANCES ARE: DECIMALS ANGLES .XX	CONTRACT NO.			ELECTROFUSION CORP.
		APPROVED	DATE		
		DRAWN M JENSEN			
		CHECKED			
	MATERIAL				
	FINISH				
NEXT ASSY	USED ON	CUSTOMER		SIZE CODE IDENT	
APPLICATION		NASA		B	
		NOT TO SCALE		SCALE:	SHEET OF



Report Documentation Page

1. Report No. 181777	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle High Temperature Be Panel Development		5. Report Date May 1989	
		6. Performing Organization Code	
7. Author(s) R. Hardesty, M. Jensen, and L. Grant		8. Performing Organization Report No. 11737	
		10. Work Unit No.	
9. Performing Organization Name and Address Electrofusion Corporation 34325 Ardenwood Blvd. Fremont, CA 94555		11. Contract or Grant No. NAS-1-18613	
		13. Type of Report and Period Covered Contractor Report	
12. Sponsoring Agency Name and Address National Aeronautics & Space Admin. Langley Research Center Hampton, VA 23665-5225		14. Sponsoring Agency Code	
15. Supplementary Notes			
16. Abstract Beryllium materials have been used for many aerospace applications over the years. Most of these applications have been fairly ambient environments. The work reported in this paper investigated the possibility of fabricating beryllium panels for high temperature applications up to 1200°F. Joining alloys were reviewed, tested and evaluated for high temperature applications.			
17. Key Words (Suggested by Author(s)) Beryllium, Brazing, High Temperature, Beryllium Honeycomb Panel		18. Distribution Statement	
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages 19	22. Price